LANDSAT APPLICATION OF REMOTE SENSING TO SHORELINE FORM ANALYSIS

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Robert Dolan
Principal Investigator

and

Jeffrey Heywood

Department of Environmental Sciences
University of Virginia
Charlottesville, VA 22903

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Quarterly Report

LANDSAT APPLICATION OF REMOTE SENSING TO SHORELINE-FORM ANALYSIS

Introduction

This is our first quarterly report submitted under Landsat Investigation No. 21240, which officially began on 3 April 1975. The overall objective of the investigation is to demonstrate the feasibility of applying remote sensing to shoreline-form analysis and to assess the usefulness of remote sensing in predicting the location of storm damage along the east coast of the United States.

Preparation for Imagery and Storms

Requisite for the success of this study are coastal storms of sufficient size to generate changes in landforms and the acquisition of data at three different scales that will be used to monitor these changes. Since such storms are not expected to occur until the fall and winter seasons, and since we have only recently begun to receive part of our imagery (Landsat), this report will emphasize the in-house preparation we have made to handle the imagery and analyze the storms when they begin to arrive. It will review the objectives of the investigation, major questions that we hope to answer, the method of approach, a description of the study sites, expected results, and the status of imagery and accomplishments to date.

The Problem

Predict Storm Damage

The primary objectives of this investigation are to determine whether or not we can predict areas of storm damage along the mid-Atlantic coastline based on interpretation of historic and recent remote-sensing imagery. The historic imagery that we are using is aerial photography ranging in scale from 1:5,000 to 1:20,000. Recent imagery will include color infra-red photography enlarged to scales of 1:5,000 and 1:60,000 and Landsat imagery enlarged to 1:250,000.

Record Landform Change

After each major storm, an assessment will be made of the storm's physical impact upon the coast through the interpretation of follow-up imagery and field verification. Changes in shoreline and vegetation line will be recorded. Data will be collected at specific sites to quantify changes in "typical" overwash processes. Other visible changes in coastal landforms, such as longitudinal movement of shoreline sand waves will be mapped.

Accomplishments

Maintain Data Bank

In addition, the historic data bank for coastal erosion/accretion, which has been established for selected sites along the mid-Atlantic coast, will be maintained. The relative merits of using the three different scales of imagery in accomplishing our objectives will be evaluated.

Following are some of the specific questions we will address during the investigation:

Issues to Resolve

1. Can locations of overwash events and storm damage be predicted based on the analysis of historical imagery?...based on the analysis of the most recent set of imagery?...based on what scale of imagery? Which method is most reliable?
2. Can we in turn classify coastal zones into categories of vulnerability with respect to physical processes, such as (a) highly stable, (b) relatively stable, (c) highly unstable? Can

such a measure of stability be quantified for purposes of comparison?

3. Can reliable shoreline erosion/accretion rates be established and can the future location of the shoreline be predicted?
4. Can we detect longitudinal movement of crescentic shoreline landforms in the current time frame of our study?...at what scale?
5. How does vegetation and island stability in general relate to shoreline stability?
6. How useful is Landsat imagery in answering the above questions?
7. Can we arrive at a single optimum scale at which changes in coastal landforms should be monitored?

Method of Approach

Three Scales of Imagery

The investigation will be based primarily on the interpretation and mapping of remotely sensed imagery at three different scales. Low-altitude photography at original scales ranging from 1:7,500 to 1:20,000 will be enlarged to 1:5,000. High-altitude photography will be studied at 1:60,000. Landsat imagery will be enlarged to 1:250,000.

Three Corresponding Study Areas

Three corresponding study areas have been defined (Fig. 1). Landsat imagery will be used to analyze the coast from Cape Henlopen, Delaware, to Cape Fear, North Carolina. High-altitude photography will cover the same area but focus especially on Assateague Island and Hatteras Island. Low-altitude photography will also cover Hatteras and Assateague but will be used specifically to coincide with field verification at selected sites. One site will be an overwash fan located three kilometers north of the Maryland State Park on Assateague. Another site will be in the vicinity of Cape Hatteras, North Carolina. Additional sites will be included depending on time, funding available for field work, and continuing analysis of new imagery.

Monitor Change

Since the investigation is concerned with monitoring change in coastal landforms, a method enabling rapid comparison of photographs of the same area taken at different points in time must be employed. The method adopted for this study was developed for low-altitude imagery under the auspices of a National Park Service

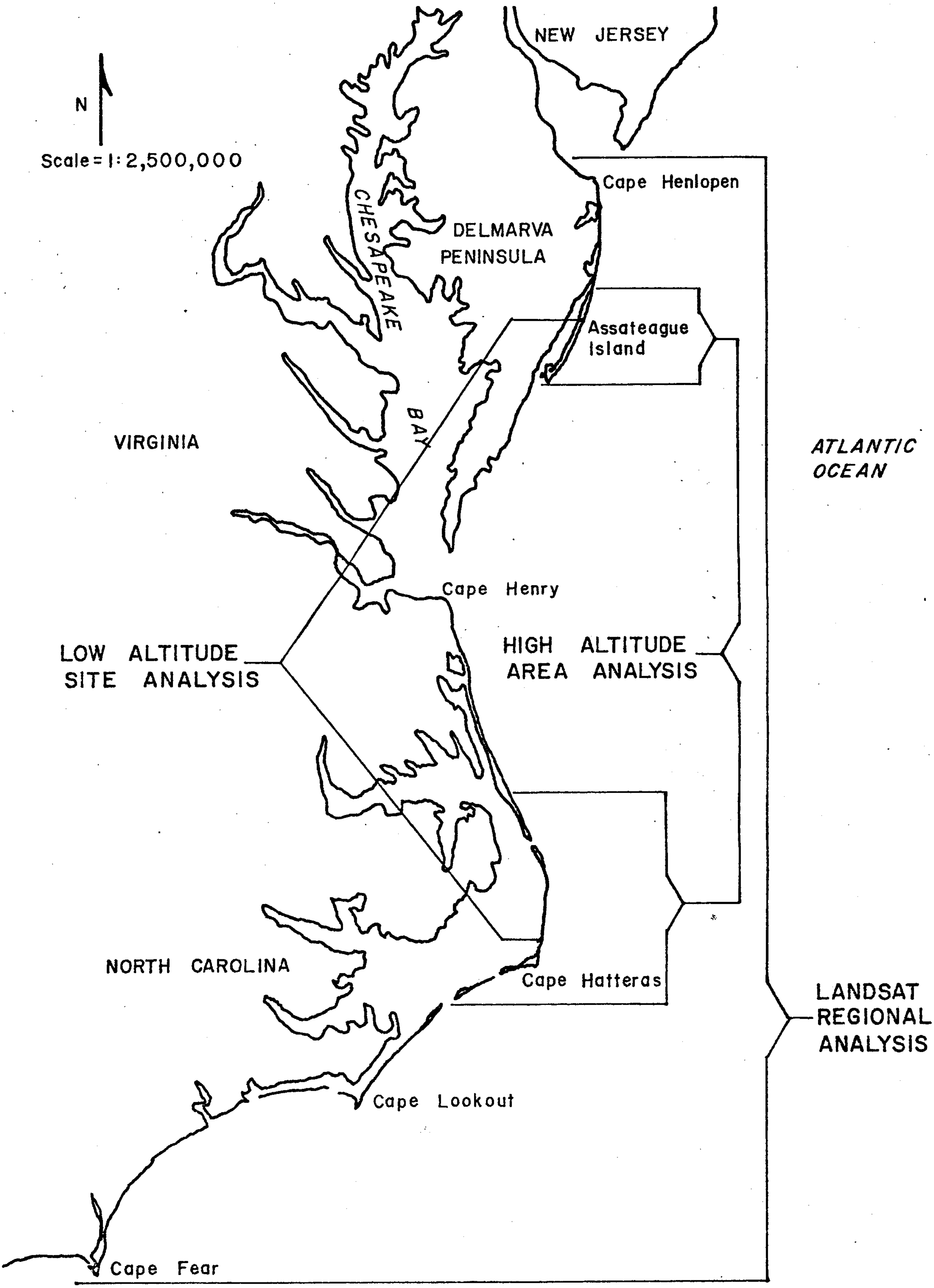

Fig. I: Study Area.

grant and supported in large part by the imagery and facilities avalable through NASA-Wallops. The method is described below for a scale of 1:5,000 but will also be adapted where possible to the two smaller scales used in this study.

Overlay Maps

Due to the varying scales of the historical photography and the need to measure relatively straight segments of an otherwise curved shoreline, base maps at the scale of 1:5,000 were created that divided the coastline into segments of 3.6 km. The base maps were drawn from enlarged sections of the most recent 7.5-minute series USGS topographic maps available. The K&E Kargyl Reflecting Projector was used for all enlarging purposes. Each base map has angular hash marks and is bordered by a rectangular frame, 11.4 cm x 6.7 cm, both of which are used for purposes of alignment. The frame of each base map is oriented with the long side parallel to the coastline and positioned over the barrier island in such a manner that the shoreline and vegetation line will fit within the frame for all years of photography and so that adjacent frames are overlapping with coincident hash marks. The long side of the frame, parallel to the coastline and lying entirely over the ocean, then becomes the base line from which all future measurements are made and, in turn, the "bottom" of the base map.

Overlay Maps

For each base map, aerial photography of a selected date is enlarged until the best possible fit of natural and cultural features between photo and base map is obtained on the projector. The shoreline and vegetation line are then drawn on an overlay map. This process is repeated for each historical photograph of the same area.

The shoreline was identified by the "line" that separates the white beach sand from the gray (in panchromatic film) or light blue (in color infrared film) beach sand and represents the high-water mark at the time the photograph was taken. This line was easily recognizable on all but the most gradually sloping beach fronts.

The vegetation line was identified by a "smoothed line" that separates the white beach or dune sand from the grey (in panchromatic film) or purple-red (in color infrared film) vegetation and represents the beginning of the zone where relatively contiguous stands of shrubbery or thick grasses interspersed with shrubbery were fairly well established.

Recording Data

An orthogonal grid system with divisions equal to 100 meters for a distance of 3,600 meters in the "x" direction (along the shoreline) and divisions equal to 5 meters for a distance of 2,100 meters in the "y" direction (across the shore) at a scale of 1:5,000 was drawn on a sheet of clear acetate with a frame identical in size to that of each base map and overlay map. At every 100-meter location along the shore, the points at which the shoreline and the vegetation line intersected the across-the-shore transect were recorded. Values of these points range from 0 to 2,100 meters to the nearest 5 meters.

Data Tabulation

A computer program has been written which lists the following information for every base map (statistics include mean, variance, standard deviation, number of transects over which mean is calculated, maximum value, and minimum value:)

1. Location of vegetation line (VL) and shoreline (SL) and overwash penetration

distance (OP = VL - SL), for each of the 36 transects along the coast.

2. Line-printer graphs of VL, SL, and OP.
3. Changes and rates of change in VL, SL, and OP between selected dates (erosion and accretion) and statistics.
4. Line-printer graphs of rates of change in VL, SL, and OP.

In addition, the following information is provided for sections of the coast of any desired length:

5. Statistics on OP for each year and statistics on changes and rates of change in VL, SL, and OP between any two years.
6. Frequency distributions of OP for each year and of rates of change of VL, SL, and OP between any two years.

The data and graphs are then analyzed to assist in answering the questions previously cited (Fig. 2). We do not expect to be able to go beyond the map-overlay stage with the Landsat imagery, at which point visual assessments of changes in coastal landforms will be

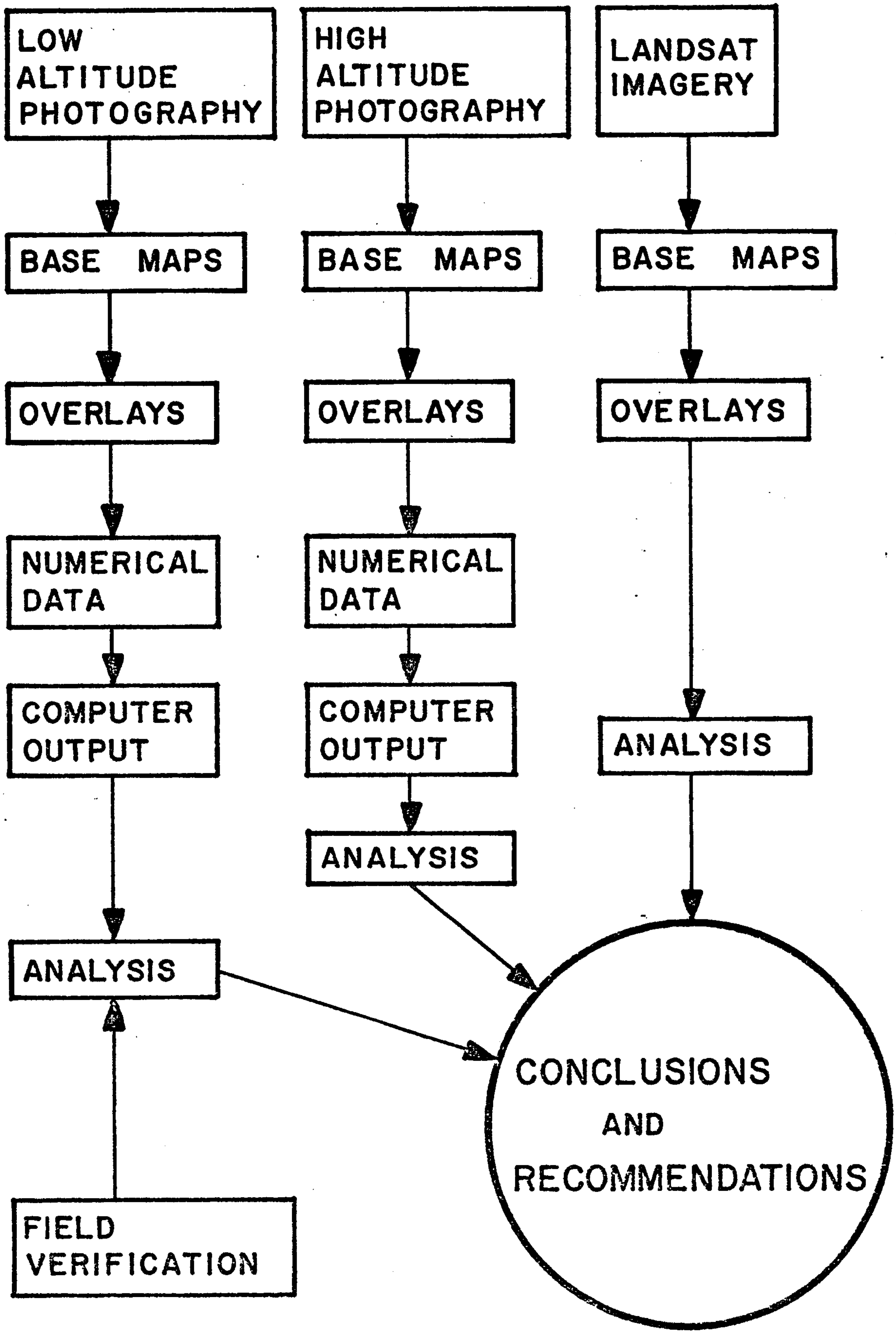

Fig. 2: Investigative Process.

made. We hope to be able to go completely through to the data-tabulation stage with the high-altitude imagery. This will require slight modification of the computer program but no change in the process of recording data. The success of this attempt must await arrival of our first set of high-altitude imagery.

Analysis

Field Measurements

Visits to selected field sites are to be made following major storms and will be coordinated with overpasses of high-altitude and low-altitude imagery support whenever possible. Large markers that will be visible in the low-altitude photography will be placed at critical points around the overwash site and appropriate measurements will be made between markers. These critical points include:

1. High-water line,
2. Vegetation line,
3. Line of farthest penetration of most recent overwash if different than vegetation line,
4. Edges of throat in overwash fan,
5. Top ridge of fore dune.

Extensive field notes will be taken describing qualitative measurements such as amount

Storm Impact

and type of material deposited in the fan, extent of dune scarping, and a visual assessment of the overall impact of the storm. An attempt will be made to assess the damage that might have occurred had man-made structures been present in the area of storm penetration.

Correlation with Imagery

Field notes and measurements will then be correlated with findings obtained through analysis of post-storm imagery. Conclusions reached at specific test sites will be related to the remainder of the study area and to similar coastlines in general.

Expected Results

The end product of the investigation will consist of four parts:

Data Set

1. Computer output of historical data representing the change of coastal landforms over time. Figure 3 is an example of a statistical summary for a section of Hatteras Island.

Map Overlays

2. Selected map overlays showing changes in coastal landforms detected in Landsat imagery and showing predicted locations of future shorelines.

CAPE HATTERAS   MAP 17/TRANSECT 3, THROUGH MAP 18/TRANSECT 34 (6.5 KILOMETERS)   TOTAL STATISTICAL SUMMARY.

FOR MEAN, +=LANDWARD MIGRATION (EROSION) FOR VEGETATION LINE AND SHORELINE, AND AN INCREASE IN OVERWASH PENETRATION DISTANCE.
-=SEAWARD MIGRATION (ACCRETION) FOR VEGETATION LINE AND SHORELINE, AND A DECREASE IN OVERWASH PENETRATION DISTANCE.

NTRANS=NUMBER OF TRANSECTS USED TO CALCULATE MEAN.
MAXACCR=MAXIMUM SEAWARD MIGRATION (ACCRETION=ABS. VAL.). IF POSITIVE, THERE WAS NO ACCRETION (MAXACCR=MINIMUM EROSION).
MAXEROS=MAXIMUM LANDWARD MIGRATION (EROSION). IF NEGATIVE, THERE WAS NO EROSION (MAXEROS=MINIMUM ACCRETION, ABS. VAL.).
MAXINCR=MAXIMUM INCREASE IN OVERWASH PENETRATION. IF NEGATIVE, THERE WAS NO INCREASE (MAXINCR=MINIMUM DECREASE, ABS. VAL.).
MAXDECR=MAXIMUM DECREASE IN OVERWASH PENETRATION (ABS. VAL.). IF POSITIVE, THERE WAS NO DECREASE (MAXDECR=MINIMUM INCREASE).

FROM -	01JUL45	01JUL45	10OCT58	13MAR62	13DEC62	03OCT68	
TO -	04JUN74	10OCT58	13MAR62	13DEC62	03OCT68	04JUN74	
YEARS -	(28.92)	(13.28)	(3.42)	(.75)	(5.81)	(5.66)	(0.00)

TOTAL CHANGE IN VEGETATION LINE (METERS)

MEAN	62.	-37.	24.	12.	-10.	71.	0.
VARIANCE	2628.	1295.	1856.	1097.	5840.	4309.	0.
STAN DEV	51.	36.	43.	33.	76.	66.	0.
NTRANS	53.	51.	50.	50.	50.	51.	0.
MAXACCR	-35.	-125.	-10.	-40.	-180.	-40.	0.
MAXEROS	200.	20.	180.	140.	145.	190.	0.

TOTAL CHANGE IN SHORELINE (METERS)

MEAN	98.	14.	38.	17.	19.	-8.	0.
VARIANCE	1409.	2252.	2188.	429.	1794.	2958.	0.
STAN DEV	38.	47.	47.	21.	42.	54.	0.
NTRANS	56.	52.	52.	52.	55.	62.	0.
MAXACCR	10.	-100.	-25.	-20.	-160.	-105.	0.
MAXEROS	210.	65.	160.	55.	135.	150.	0.

TOTAL CHANGE IN OVERWASH PENETRATION (METERS)

MEAN	-36.	-52.	-9.	-4.	-35.	66.	0.
VARIANCE	2232.	2874.	3411.	1350.	3119.	3423.	0.
STAN DEV	47.	54.	58.	37.	56.	59.	0.
NTRANS	53.	51.	50.	50.	50.	51.	0.
MAXINCR	105.	40.	110.	120.	75.	215.	0.
MAXDECR	-155.	-190.	-160.	-90.	-165.	-60.	0.

FROM -	01JUL45	01JUL45	10OCT58	13MAR62	13DEC62	03OCT68	
TO -	04JUN74	10OCT58	13MAR62	13DEC62	03OCT68	04JUN74	
YEARS -	(28.92)	(13.28)	(3.42)	(.75)	(5.81)	(5.66)	(0.00)

RATE OF CHANGE IN VEGETATION LINE (METERS/YEAR)

MEAN	2.2	-2.8	7.1	16.5	-1.6	12.5	0.0
VARIANCE	3.1	7.3	158.7	1950.5	173.0	134.5	0.0
STAN DEV	1.8	2.7	12.6	44.2	13.2	11.6	0.0
NTRANS	53.0	51.0	50.0	50.0	50.0	51.0	0.0
MAXACCR	-1.2	-9.4	-2.9	-53.3	-31.0	-7.1	0.0
MAXEROS	6.9	1.5	52.6	186.7	25.0	33.6	0.0

RATE OF CHANGE IN SHORELINE (METERS/YEAR)

MEAN	3.4	1.1	11.2	22.8	3.3	-1.4	0.0
VARIANCE	1.7	12.8	187.1	762.3	53.2	92.3	0.0
STAN DEV	1.3	3.6	13.7	27.6	7.3	9.6	0.0
NTRANS	56.0	52.0	52.0	52.0	55.0	62.0	0.0
MAXACCR	.3	-7.5	-7.3	-26.7	-27.5	-18.6	0.0
MAXEROS	7.3	4.9	46.8	73.3	18.1	26.5	0.0

RATE OF CHANGE IN OVERWASH PENETRATION (METERS/YEAR)

MEAN	-1.2	-3.9	-2.7	-5.6	-6.0	11.7	0.0
VARIANCE	2.7	16.3	291.6	2400.7	92.4	106.9	0.0
STAN DEV	1.6	4.0	17.1	49.0	9.6	10.3	0.0
NTRANS	53.0	51.0	50.0	50.0	50.0	51.0	0.0
MAXINCR	3.6	3.0	32.2	160.0	12.9	38.0	0.0
MAXDECR	-5.4	-14.3	-46.8	-120.0	-28.4	-10.6	0.0

TOTAL OVERWASH PENETRATION FOR EACH DATE (METERS)

DATE -	01JUL45	10OCT58	13MAR62	13DEC62	03OCT68	04JUN74	
MEAN	152.	94.	83.	78.	45.	114.	0.
VARIANCE	2659.	2620.	1402.	2506.	497.	2630.	0.
STAN DEV	52.	51.	37.	50.	22.	51.	0.
NTRANS	55.	51.	50.	50.	51.	53.	0.
MAXIMUM	250.	250.	215.	210.	115.	255.	0.
MINIMUM	85.	40.	25.	15.	10.	5.	0.

Fig. 3: Statistical Summary of Landform Change for A Section of Hatteras Island.

Supporting graphics will be included.

Landform Comparisons

3. Graphical comparisons showing coastal landform trends, analysis, predicted storm impact, and actual storm impact for selected sections of the coast. An example of how such comparisons might look is shown in Figure 4. These figures are based on fictitious data and are presented for illustrative purposes only.

Discussion

4. A complete discussion of the investigation including a review of objectives, the method of approach, results of analysis, conclusions, recommendations, and other pertinent information. The items discussed in this progress report will be as closely adhered to as possible but will depend on the timely flow of imagery and the occurrence of significant storm activity.

Imagery Requirements

This investigation is based on the assumption that there will be coastal storms during the fall of 1975 and the winter of 1976 of sufficient

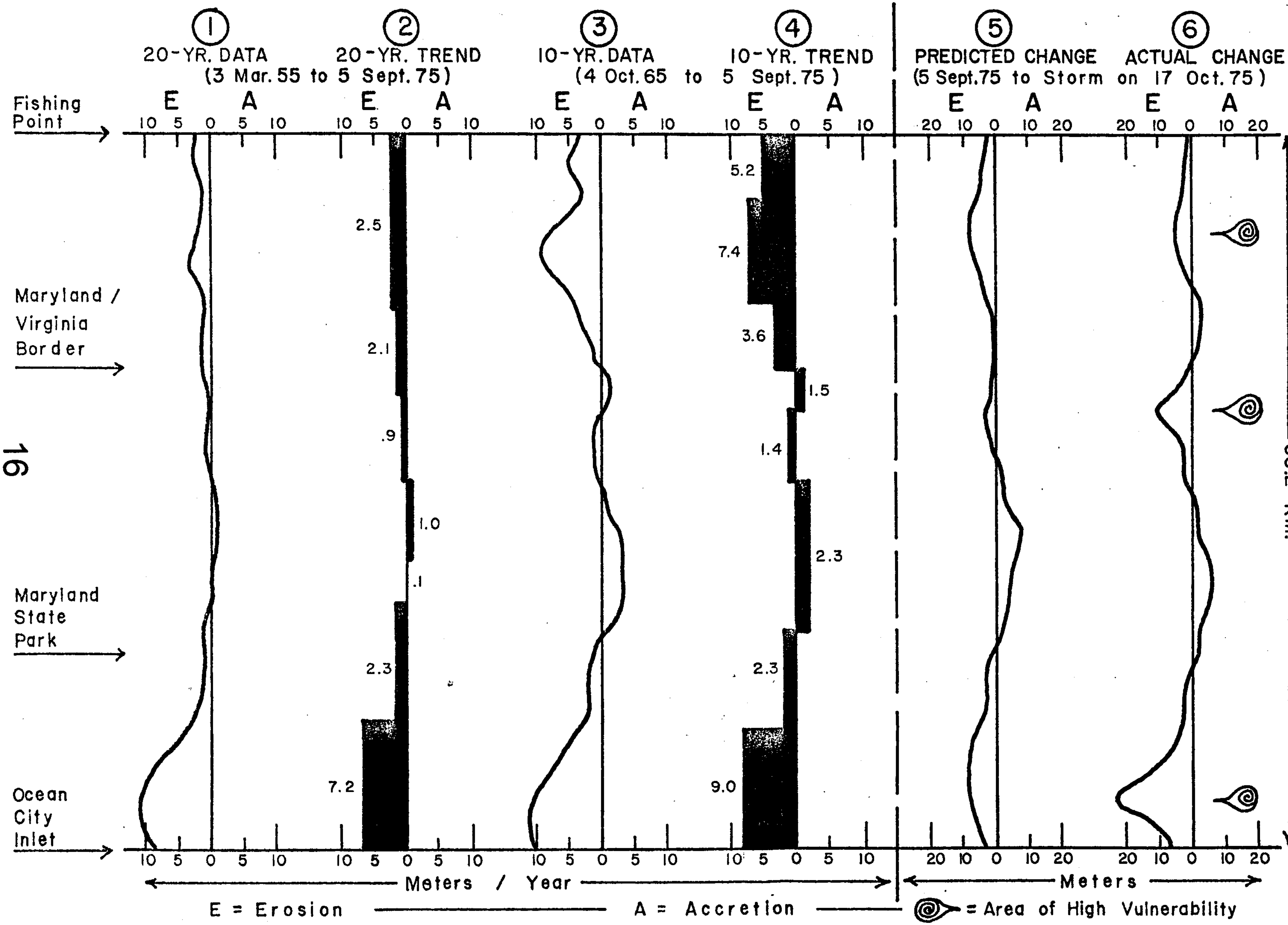

Fig. 4. Shoreline Comparisons for Assateague Island

Prediction Reliability Table

(to accompany Figure 4)

Criteria	Predicted	Actual	Reliability (%)
Percentage of shoreline eroded	77%	60%	72
Percentage of shoreline accreted	21%	39%	54
Mean shoreline erosion	4.1 m/yr	5.3 m/yr	77
Mean shoreline accretion	3.2 m/yr	3.1 m/yr	97
Aggregate percentage of reliability			75

Dependent on Imagery

magnitude to cause overwash events and associated changes in landform. It is totally dependent on the availability of pre-storm and post-storm imagery. In order to properly address the questions presented in this report, the following imagery is required:

Landsat

1. Landsat imagery of the mid-Atlantic coast from Cape Henlopen, Delaware, to Cape Fear, North Carolina, for every satellite pass from May, 1975, through the end of the storm season in April, 1976. A single 20" x 20" black and white print of MSS Band 6 for each frame would be more valuable than one 70 mm transparency per band (total of 4) for each frame.

High Altitude

2. High-altitude (1:60,000 scale), color infrared prints from Cape Henlopen, Delaware, to Cape Fear, North Carolina, prior to the first storm expected in September and following each major storm through April. Prints are preferred to transparencies and 60% overlap is desirable but not necessary.

3. Low-altitude (1:10,000 scale), color infrared prints of Assateague Island

Low Altitude

from Ocean City Inlet to Chincoteague Inlet and Hatteras/Ocracoke Islands from Nags Head to Ocracoke Inlet prior to the first storm in September and following each major storm through April. Prints are preferred to transparencies and 60% overlap is desirable but not necessary.

Close communication must exist between this office and the supplier of aerial photography so that a major storm can be identified as such when it occurs. All frames must include the shoreline and as much of the barrier island as possible. This becomes a critical situation only in low-altitude imagery.